TL-Shaped Circular Parasitic Compact Planar Antenna for 5G Microwave Applications

Ridhi Gupta, Manish Varun Yadav, and Swati Varun Yadav

Abstract TL-Shaped Circular Parasitic Compact Planar Antenna for 5G microwave applications is proposed and investigated. The current structure is complex and size efficient. The antenna's front side consists of rectangular patch in center that consists of L-shaped, T-shaped and inverse T-shaped elements, respectively, with four parasitic rings on the top and microstrip line in center fed up by 50 Ω strip line. Backside of antenna consists of three parasitic rings on the top, four horizontal strips arranged in increasing order and ground plane with small rectangular slot in it. Using CST Microwave Studio, antenna simulations are performed on the FR-4 substrate with the overall dimensions of 13 * 15 * 1.5 mm^3. The antenna offers an impedance bandwidth of 60.8% and a return loss of − 28 dB, with a frequency range of 3.2–6 GHz and a central frequency of 4.6 GHz. Radiation patterns from the proposed structure are constant throughout the operational range. Proposed antenna having stable polar patterns and efficient performance. The antenna is appropriate for 5G microwave communication applications since it has a wide gain of 4.81dBi and an efficiency of 82%.

Keywords 5G antenna · Microwave application · High efficiency · Impedance bandwidth · High gain

R. Gupta · M. V. Yadav (✉)
Department of Aeronautical and Automobile Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka 576104, India
e-mail: yadav.manish@manipal.edu

R. Gupta
e-mail: ridhi.gupta@learner.manipal.edu

S. V. Yadav
Department of Instrumentation and Control Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka 576104, India
e-mail: yadav.swati@manipal.edu

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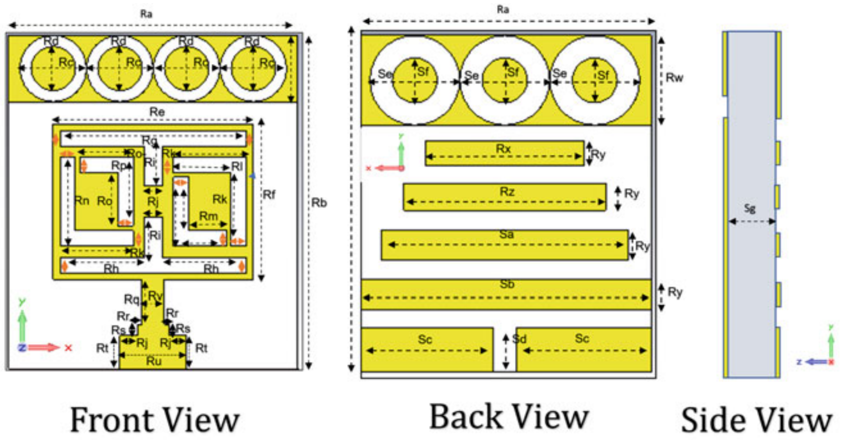
1 Introduction

Antennas play a crucial role in aerospace communication by transmitting and receiving radio signals between aircraft, satellites, and ground stations. A wide range of antennas, including semi-circular, L-shaped, triangular, multi-slot, and U-shaped antennas, are used in aerospace communication [1–6]. Techniques like changing the ground plane with parasitic elements, adding a small fractal component, U-shaped or circular slots, and circles are discussed to enhance their performance [7–11]. Polar radiation patterns can be created by altering the circular patch or by cutting a rectangular piece [12–14]. Previous research has shown that a wideband aerospace band can be created by changing a patch with a defective backside and semi-circular slots [15, 16]. As stated in references, altering the backside by modifying slots leads to a patch element with a defective plane [2, 17]. According to studies [18, 19], one method involved the use of a flexible antenna and “dumbbell-shaped” radiator. A long strip patch with cut rear slots is another design modification noted in reference [20], which improves current flow. The literature presents various design options for planar antennas. To generate balanced radiation patterns, one suggestion is to use a modified backside with precisely trimmed circular holes, as shown in references [21, 22]. The addition of a rectangular patch to the edges increases oscillations, as per reference [23, 24]. A fractal antenna design has been demonstrated to achieve high gain, as stated in reference [25]. Impedance matching reported through the design of multi-slots [26], The L-shaped design has been shown to reduce band resonance, as stated in reference [27]. More information on the antenna design, development, and simulated outcomes is provided in other sections of the paper.

2 Geometry and Design Principle

Figure 1 illustrates the geometry and concept for the design of an antenna. Substrate used in the antenna design is FR-4 inscribed on copper annealed with overall dimensions as 13 mm * 15 mm * 1.5 mm. The Ra and Rb represent the width and length of antenna, respectively. The parameter values for the design are displayed in Table 1 (given in mm). The length ‘Rq’ and width ‘Rv’ of the microstrip line are 2 mm and 1.5 mm, respectively, and are connected to the substrate’s thickness, denoted by ‘Sg’. The front part of the antenna is created by parasitic circular rings, rectangular patch, T, and inverse T with microstrip line. The outer and inner diameters of circular parasitic circular ring are denoted by ‘Rc’ and ‘Rd’. The length and width of inner rectangular patch are defined as ‘Re’ and ‘Rf’. With a partial ground plane and a rectangular slot, the antenna’s back portion has ‘Sd’ and ‘Sc’ as its length and width, respectively. Backside also consists of four horizontal strips arranged in increasing order with width as ‘Rx’, ‘Rz’, ‘Sa’, and ‘Sb’, respectively, with width denoted by ‘Ry’. Three parastic sring are placed on the top of the back plane and it is denoted by

“Se” and “Sf” as outer and inner radii of the circular rings. Parasitic elements help to resonant the lower order band.



Parameters	Ra	Rb	Rc	Rd	Re	Rf	Rg	Rh	Ri	Rj	Rk	Rl	Rm	Rn	Sc	Sd	Se
Values (mm)	13	15	3	2	9	7	8.4	3.8	1.8	0.8	3.3	2.6	1.7	4	6	2	4
Parameters	Ro	Rp	Rq	Rr	Rs	Rt	Ru	Rv	Rw	Rx	Ry	Rz	Sa	Sb	Sf	Sg	↔
Values (mm)	2.4	3.1	2	0.2	0.5	1.5	3	1.4	4	7	1.3	9	11	13	2	1.5	0.7

Fig. 1 Proposed antenna structure

Table 1 Comparison of published planar antennas

Refs.	Band obtained (GHz)	Peak Gain (dBi)	Fractional B/W (%)	Peak (η) (%)	Overall volume (in λ)
[2]	3.1–22	1.7	150	NA	0.28λ * 0.25λ * 0.016λ
[2]	3.1–11	5.1	110	89	0.20λ * 0.25λ * 0.015λ
[6]	3.9–14	3.5	142	75	0.26λ * 0.26λ * 0.019λ
[8]	2–9	4.5	127	62	0.33 λ * 0.22λ * 0.1λ
[12]	3.5–19	3.2	145	81	0.23λ * 0.23λ * 0.015λ
[15]	3.1–11	2	109	60	0.55λ * 0.41λ * 0.022λ
[17]	2.9–16	5.2	139	87	0.33λ * 0.24λ * 0.014λ
[22]	2.8–12	2.79	122	72	0.18λ * 0.14λ * 0.15λ
[25]	2.7–7.3	2.3	108	78.3	0.32λ * 0.2λ * 0.014λ
[26]	3.1–11	2.2	110	69	0.14λ * 0.18λ * 0.015λ
[27]	2.3–11	2.1	129	70	0.2λ * 0.3λ * 0.014λ
Presented	**3.2–6**	**4.81**	**60.8**	**82**	**0.13λ * 0.16λ * 0.016λ**

3 Result and Discussion

Based on an analysis of their impacts on the S11 parameter and other simulated results, the proposed structure optimizes the result.

Figure 2 is showing simulated return loss of the proposed antenna. The antenna's gain is another important parameter that indicates the strength of the transmitted signal. The maximum radiation effectiveness is shown within 3.3–5.2 GHz frequency range. The proposed design's simulated antenna efficiency and gain vs. frequency curve is depicted in Fig. 3. Peak gain, with a value of 4.81 dB, is seen at 4.5 GHz. Maximum radiation efficiency of antenna is observed at 4.25 GHz having a value of 0.82 or an efficiency of 82%. As the frequency rises, ohmic losses increase, leading to a gradual decline in antenna efficiency at higher frequencies.

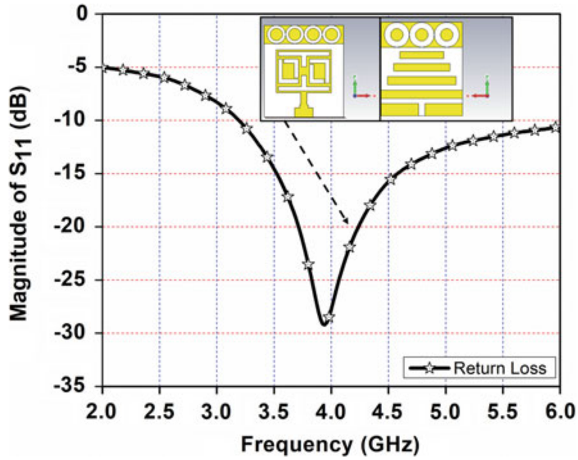


Fig. 2 Simulated return loss

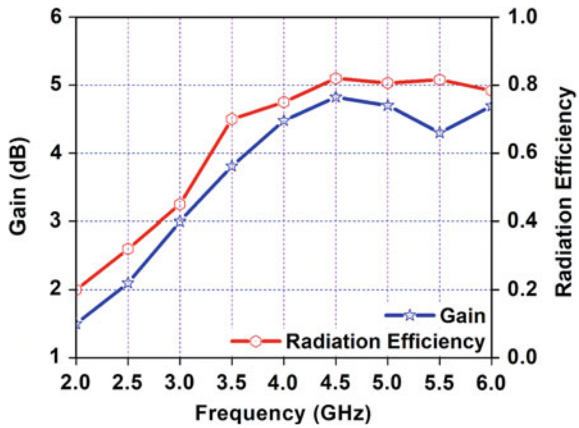


Fig. 3 Gain and antenna efficiency curve

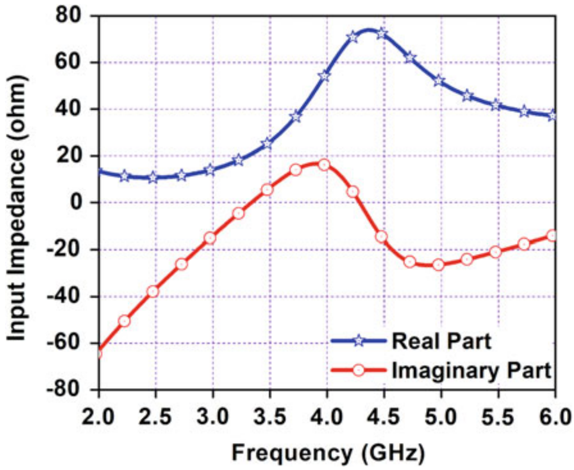


Fig. 4 I/P impedance curve

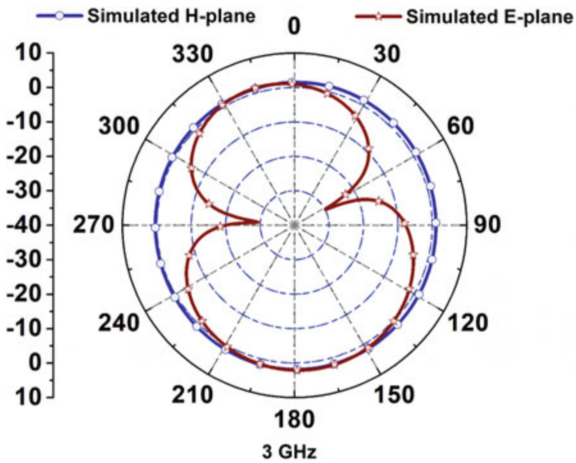


Fig. 5 Radiation pattern

Figure 4 displays an I/P impedance curve that reflects the frequency curve for the proposed design's simulated real and imaginary components. The behavior is inductive within the 3.2–4.2 GHz frequency range, followed by a capacitive behavior. The inductive behavior is represented by a positive polarity, whereas a negative polarity indicates capacitive behavior. The curve illustrates the impedance normalized to 50 Ω.

Figure 5 depicts the 5G antenna's 3.5 GHz polar pattern, in two orthogonal coordinates: both H- and E-plane patterns. The radiation pattern improves the ability to identify the radiation pattern at a specific frequency by displaying measured and simulated H- and E-plane radiation patterns. Two perpendicular planes depict the radiation pattern, one of which represents the E-field and is oriented at a 90-degree angle to the YOZ plane, and the other of which represents the H-field and is oriented at a 0-degree angle to the XOZ plane. The radiation pattern remains stable, and the antenna is coherent.

The current field distribution of the 5G antenna is presented in the paper. Figure 6 displays the current distributions from a front-to-rear perspective. The equivalent surface of the antenna represents its radiated current field and highlights its signal strengths, with the ability to generate both E-field and H-field, indicating significant signal strength in the design. Depicts the simulated radiation lobe pattern of the 5G antenna. The front plane of the structure and the frequency distribution of the 2D-vector surface current (at 3 GHz) are shown in Fig. 7. The radiated field will closely mirror the surface current of the original antenna by substituting similar surface currents for the antenna. This indicates that even in the absence of the main current source, the surface current can help to detect radiation.

Comparison table with previously published antenna is shown below, and our proposed TL-Shaped Circular Parasitic Compact planar antenna for 5G microwave applications is satisfy the requirement of all antenna parameters.

4 Conclusion

This research proposes a circular TL-shaped parasitic planar antenna for 5G applications. The proposed planar antenna has been measured, and the findings were subjected to a comprehensive analysis having dimensions of 13 * 15 * 1.5 mm^3. Efficiency for the suggested radiator is 82% and a high gain of 4.81 dBi. Impedance bandwidth of design is 60.8%, a 4.5 GHz center frequency, and a 3.2–6 GHz frequency range. There is an intense radiation signal visible in the E-/H-field current distribution. Suggested design has totally stable radiation pattern. The distribution of surface currents shows a significant signal. This ‘TL’-shaped antenna is suitable for 5G microwave communication applications.

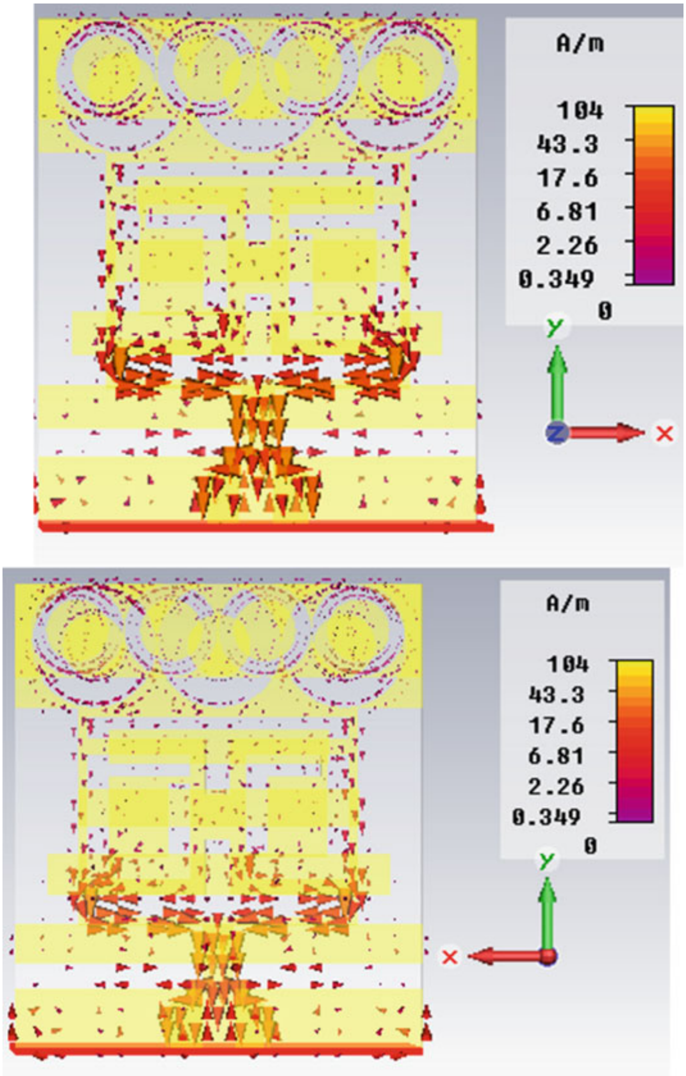


Fig. 6 Surface current distribution

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